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Capabilities of Data Processing in the Transition from Manual to Mechanical Records in Colleges and Universities

William Henry Bell Jr.

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A Thesis

By

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CHAPTER I

THE PROBLEM AND DEFINITIONS OF TERMS USED

The increasing educational diversification, dispersement of facilities, increasing maintenance costs and increasing emphasis on student services create problems that require advances in integrated educational information systems. Business and industry of all types have been forced through economic necessity to find better and faster ways of accomplishing their tasks in order to meet the competition of the times, and one very large area into which automation has been introduced is in that of clerical work involved in processing records of all types. The past ten years have seen a tremendous increase in the number of International Business Machines (IBM) and many other installations in schools of higher learning. Many more institutions are now contemplating the addition of such equipment to handle the huge influx of students who will approximately double the present college enrollment by 1975, based upon present population trends.

I. THE PROBLEM

Statement of the problem. It was the purpose of this thesis (1) to define Data Processing as a problem in terms of the lack of knowledge some have of its functions and capabilities; (2) to give background information showing the development of the field; (3) to show how and why the switch is made from manual to mechanical records; (4) to introduce the computer and its components; (5) to show the functions of the Data Processing Department; and (6) to present ideas and guidelines for organizing a Computer Center.

Importance of the study. The problem as stated above indicates that the trend toward mechanization of all phases of business life in America has progressed to the point that many of the nation's colleges and universities have utilized the punched card as a medium for expediting the tremendous volume of detail involved in maintaining adequate and accurate records for the individual collegiate student. This study will attempt to show the advantages and/or disadvantages of changing from a manual to a mechanical system of record keeping.

II. DEFINITIONS OF TERMS USED

Punched card data processing. Throughout this thesis, the term "Punched Card Data Processing" shall be interpreted as meaning the profession in which data is processed and reports are prepared by the use of punched cards on equipment designed to read holes punched in the cards. The purpose of punched card data processing is to transcribe data from source documents into a punched card form and to process the data into reports suitable for administrative consumption.

Electronic data processing. This system consists of a combination of units including input, storage, processing, and output devices, designed to handle data at electronic speeds with self-checking accuracy. The key element of the system is a high-speed electronic computer.

III. ORGANIZATION OF REMAINDER OF THE THESIS

Chapter II gives the historical background of data processing starting with finger calculations and the abacus through the invention of the first punched card machine. It tells of the development of the International Business Corporation and the Remington Rand Corporation.

Chapter III discusses the principles of punched card data processing with special emphasis on "unit record equipment." The design and use of the punched card, sorting, collating, printing and report preparation are the main points of the chapter.

The title of Chapter IV is "Introduction to Electronic Computers," and the chapter is broken into three parts. They are" (1) computer characteristics, (2) programming and, (3) growth of computers. This chapter separates the computer into component parts and shows what is necessary for the successful operation of the machine.

Chapter V gives ideas that must not be overlooked in planning or organizing a computer center. These ideas are the work of a group of computing center directors sponsored by the National Science Foundation and are based on experience in operations of all types of college and university computing centers over a period of years.

Summary and conclusions are found in Chapter VI.

CHAPTER II

HISTORICAL BACKGROUND

Until the nineteenth century, people found business calculations a very complex job, because they had to be done "in the head." This was so primarily because writing materials were very scarce and, therefore, too expensive to use for ordinary purposes. Paper was probably made by the Chinese before the time of Christ, but it was not until the fourteenth century A.D. that the science of paper making spread into Europe. Paper made from pulp was an invention of the nineteenth century.

The lack of paper caused people to do most of their calculations mentally, with the aid of their fingers. Simple additions were carried out by finger tallying. For example, to add five and two, one holds up two fingers, then five more fingers, and counts the total number of upraised fingers to get the result of seven. When more complex forms of calculation were devised, they were initially performed by the use of fingers. Finger training was so important that it was taught in Roman schools, and various methods were devised to do "advanced" operations such as multiplication and division.

The experienced calculators of early times performed their calculations by the use of a device containing pebbles or beads strung on a string called an "abacus", or a counting board. The abacus was used efficiently in addition and subtraction. However, even when it came to multiplication or division, limited historical data show that many people have used the abacus for these purposes, too. Multiplication was done by repeated addition, and division was done by repeated subtraction: a method which is at present performed by digital computers. (1: pp. 15-17)

Our number system, based on the use of ten fingers, is of Hindu origin and was modified in India into what we now call the "Arabic Numerals." Because of the widespread use and knowledge of the Arabic system of numeration in Christian Europe around the thirteenth century, mathematicians began to develop computing devices to calculate at a much higher level than that of the abacus. The first of such devices was the numerical wheel calculator (the world's first adding machine), made around 1642 by Blaise Pascal of Paris at the age of 18. He was interested in building it because he wanted to aid his father, who at that time was the superintendent of taxes. His calculator was capable of registering decimal value by the rotation of the wheel by one to nine steps, with a carry lever to operate the next higher digit wheel as a given wheel exceeded 10 units of registration. It is considered the first real calculating machine to be developed.

Gootfried Wilhelm von Leibnitz showed in 1673 how a mechanical multiplier could be made. He felt that multiplication could be treated like addition. He stated that multiplying 5 X 4 means 5 added to itself four times or 4 added to itself five times. In this case, two counters would be needed: One to perform the addition and the other to show when addition should stop. Division was looked upon as the reverse of multiplication, and subtraction was adding the second quantity in reverse. Thus, these four basic arithmetic operations were based on counting. Leibnitz built his "Stepped-Wheel" machine when he was about 25 years old. It was later manufactured in 1694. However, this machine, as well as that of Pascal was not considered dependable in its operation.

One of the more dependable and successful calculating machines was developed in 1820 by Charles Xavier Thomas, of France. It performed all the four functions of arithmetic. In 1872, Frank Stephen Baldwin, of the United States, introduced a calculating machine and began building his machine a year later, thus marking the beginning of the calculating-machine industry in the United States. (1: pp. 21-22)

The use of punched card equipment for data processing dates back to the year 1887. It was that year that Dr. Herman Hollerith, a statistician employed by the United States Government, developed the first statistical machine operating on the principle of holes punched in cards. This was not the first device to employ punched cards to activate a machine, but it was the first one developed to record, compile and tabulate data.

The first successful machine to operate from punched cards was a textile loom invented in 1801 by a Frenchman named Joseph M. Jacquard. This loom was capable of weaving beautiful intricate designs into cloth according to instructions given it by punched cards. The machine was not accepted at first; in fact, in Lyons, where Jacquard attempted to introduce it into general use, he was mobbed and his loom burned. Jacquard, not easily discouraged, managed to gain the interest of Napoleon. With the support of the government the loom soon became a tremendous success and the French government was so grateful to Jacquard for his invention that it granted him a pension for life.

It was not until 1887, 86 years after the fabulous success of the Jacquard loom, that another successful punched card machine was developed. The compilation of the United States Census had grown into a monumental task, and it was obvious that the 1890 census could not be processed under existing systems. Dr. Herman Hollerith, who was working on the census, became interested in the problem and started inventing a machine. By 1887, he had developed a machine, very crude by today's standards, designed to record, compile and tabulate census data by the use of a punched paper tape. As a result of Dr. Hollerith and his invention, the 1890 census was completed in one-fourth the time required for the 1880 census.

In 1896 Dr. Hollerith organized the Tabulating Machine Company to develop his machines for commercial sales. In the meantime, S. N. North, Director of the Bureau of Census was still not completely satisfied, and desired better equipment to use in the 1910 census. He selected James Powers, a little known statistical engineer who had displayed some originality in ideas for processing masses of statistical data to develop a new system. Powers shrewdly obtained agreement to retain his right to patent any machine which he might develop.

Powers patented his first punching machine in 1908. It was capable of punching a 20-column card and employed two previously unknown principles of operation which are still used on Powers' machines. These two principles are "simultaneous punching," and "metal to metal contact."

"Simultaneous punching" is the method by which an operator keys in all of the information to be punched in the card, and then presses a key to cause all of the punching to be done simultaneously. This permits the operator to correct an error before the card is punched, a process not possible under the serial-punching principle whereby a column is punched each time a key is depressed. "Metal to Metal contact" is the positive contact of the punch dies with the stud which provides a high degree of accuracy in registration. These two principles of operation were so successful that as late as 1954 both were still being employed in all punching machines built by Remington-Rand. The success of these machines encouraged Powers to start the Powers Accounting Machine Co. in 1911.

The 15 year old Tabulating Machine Co. organized by Dr. Herman Hollerith merged with the International Time Recording Co. of New York, and the Dayton Scale Co. and the new company was called the Computing-Tabulating-Recording Co. In 1914, this company managed to attract a highly successful executive named Thomas J. Watson to manage the company. Ten years later, in 1924, the name of the company was changed to International Business Machines Corp.

The Powers company merged with several other office supply companies in 1927 to form the Remington Rand Co. In 1955, Remington Rand merged with Sperry Gyroscope to form the Sperry-Rand Corp. The punched card equipment is marketed through the Remington Rand Univac Division of the Sperry-Rand Corp.

In 1933, IBM acquired a company called Electromatic Typewriters, Inc. which is now considered the typewriter division of IBM. In 1943 they sold the Dayton Scale Division to the Hobart Manufacturing Co. The IBM World Trade Corp. was organized in 1949 as a wholly owned subsidiary to handle foreign business. Thomas J. Watson placed tremendous emphasis on engineering and sales and, as a result, IBM because so powerful in the punched card equipment field that the U. S. Government began to eye it as a monopoly. The company was threatened by anti-trust suits. Thomas J. Watson, Jr., who took over the helm upon retirement of his father, wisely took actions to avoid being prosecuted. The IBM Service Bureau Division was split off and made a wholly owned subsidiary of IBM called the Service Bureau Corp. Service bureaus throughout the country were physically detached from the main office and moved into separate quarters, where they set up their own management and began to operate as separate businesses. IBM also sold the Time Recorder Division to Simplex in 1959, in order that it might devote more attention to the engineering of more and better punched card equipment and computers. Other companies were encouraged and even assisted by IBM in entering into competition with them. This was especially true in the manufacturing of cards, control panels and wires. (15: pp. 13-16)

The name of Thomas J. Watson has become a legend in the punched card field. A powerful executive with high moral standards and direct aggressiveness, he placed the company in the top position it holds today by constant emphasis on the engineering of a better product and a dignified, positive approach in sales. He made the IBM trademark "THINK" famous throughout the world.

CHAPTER III

PRINCIPLES OF PUNCHED CARD DATA PROCESSING USING UNIT-RECORD EQUIPMENT

The most direct method of processing business documents would be to use each source document in its original state without converting it into a code or transcribing the data on it into another form. Ideal as this would seem, it is impossible for the following reasons: (1) too many different document sizes and shapes. (2) too many different transactions on a single document. (3) too many different styles and methods of recording data on documents.

In order for documents to be processed by machines, it is imperative that they be at least similar in size, shape, and thickness. The problems of engineering a machine capable of feeding all of the various documents used by a company are obvious. It might be possible, however, to standardize the size of source documents if this were the only problem involved. The task of standardizing throughout industry in order that machines could be used interchangeably by all companies would be tremendous, but it could be done. Some attempts have been made at this on individual types of source documents. An example of this is checks. Most checks written today fall within accepted dimensions, and high-speed machines have been developed to sort these checks at the banks. This shows that progress has been made, and if this were the only obstacle in the processing of source documents by machines, it might be possible to overcome it.

The second obstacle makes a standard processing machine impossible. One source document may contain several different transactions. This makes sorting and tabulating by machine impossible. For example, a machinist who fills out a job time card each day to record the different jobs on which he works and the time spent on each job. Assume that he worked on jobs A, B, and C during the day, spending four hours on job A, three hours on job B and one hour on job C. He would record three lines on his job time card and the total of the three would be eight hours. If totals by employee were desired, it would be easy to obtain this information from the source document because all charges for each employee are on the same source document. Let us suppose, however, that totals are desired by job. Our machinist was just one of many employees throughout the company who worked on jobs A, B, and C. It would be impossible to sort the source documents to job because the machinist's card would have to position in three different places at the same time. One logical solution to this problem is to write each transaction on a separate document but this might add so greatly to the volume of documents to be processed that it would be unreasonable.

The third obstacle is presented by the infinite number of characteristics in styles and methods used to record data on documents. If all documents could be typewritten, it would be possible to standardize on a block-type letter which could be machine sensed. But, it is neither economical nor practical to typewrite all documents. Some progress has been made in the development of machines that will read hand-written documents; however, a satisfactory product has not appeared on the market as yet. The reading of data recorded on a source document is extremely important, because the machine is useless unless it can sense and understand the recorded data and perform desired operations with it. Even if a machine was developed which would feed all sizes and shapes of source documents at high speeds, and even if there was a separate document for each transaction, it would all be in vain unless the machine was capable of sensing the data recorded on the documents and possessed the "machine intelligence" to know what to do with it. (15: pp.24-25)

Much of the success of punched card data processing can be attributed to the fact that it has hurdled all three of these obstacles.

The standard punched card is a rectangular paperboard that measures 7 3/8" long by 3 1/4" wide by .007" thick. It is a "unit record" because only the data related to one transaction are recorded on a given card. (1: p.31)

The punched card serves a variety of uses in a punched card data processing system. First, it is an input media which enters information into the machines (which cannot read ordinary written material) in a form in which they can accept information. The card also provides an output from these machines. In other words, the punched card is the principal media through which men communicate with the machines. Secondly, the punched card is a common communication media between the various specialized machines which are used in punched card processing. It is the connecting link that ties together a long series of processing steps which culminate in the production of the desired results. Thirdly, the punched card performs the function of storing information in the form of machine processable files, so this information will be available for use when it is required. And lastly, the punched card may in certain cases be a document (such as a check, time card) which has a use in the organization that does not depend upon the fact that holes are punched in the piece of paper.

The punched card is frequently referred to as a "mobile unit record." The word unit implies that the information concerning a single transaction is recorded on a single card -- one and only one transaction per card. The word mobile implies that these unit records may be rearranged and reprocessed at will to allow the transaction to be incorporated into the various reports which it affects. Thus, by recording the information once on a punched card, it may be posted to different accounts, ledgers, or reports by a mechanized process without additional human effort and without the transcription errors that are so prevalent in manual data processing. This concept of mobility is of such great importance that a rule of thumb is frequently applied which states that the information should be used in at least three different postings in order to qualify as a good punched card application.

One of the basic requirements associated with mechanized data processing is that information to be entered into the machines be recorded in a rigid format. The information is identified to the machine as an employee number or a dollar amount by means of its position alone. That is to say (in terms of punched cards) that the column or columns in which a number is recorded is the only means by which the machine can identify the information; hence, this location becomes the key to meaningful processing. Each type of transaction is recorded on cards of a specific format so that each unit of information occupies the same position on all cards for a particular type of transaction.

A group of card columns that is assigned to a particular unit of information (such as a name, hourly rate, description, cost, or tax class) is called a field. In designing the format of the punched card, the eighty columns may be grouped together to form fields in any way that seems desirable, subject to the restriction that the total number of columns in all the fields may not exceed the number of columns available on the card. Enough columns must be allowed to each field to permit recording of the largest number or the longest group of alphabetic characters that may occur among the units of information that are to be recorded in that field. For example, if price may range from 25¢ to $850.00, a five-digit field must be assigned to price; whereas, if the price could go as high as $1,000.00, a six-digit field would be required. Numeric fields are customarily justified to the right, and zeros are inserted to the left of small numbers to completely fill the columns allocated. Thus, in a five-digit field, 745 would be recorded as 00745. Alphabetic fields are customarily justified to the left, and unused columns to the right are left blank. It must be remembered that any one transaction contains a certain number of details called units of information. A "field" is a group of consecutive card columns reserved for a specific unit of information.

One of the important preliminary steps in utilizing punched card equipment for data processing is that of designing the cards that are involved. Several considerations are involved in allocating the card columns among the various pieces of information, such as the total amount of information to be recorded, the sequence in which the fields should appear on the cards, and the relationship of the location of a specific field on one card form to the location of the same field on another card form. It is not necessary that there be any relationship between the sequence of fields on the cards and the location of the information on the reports that are produced. Once the allocation of the fields is made, special forms may be printed designating the uses to which each field is put.

The different cards that enter into the processing of data usually have different formats, and may be made of different colors of paper or be identified by different corner cuts or horizontal stripes of various colors. The machines do not detect color nor do they read the information printed on the surface of the card. A blank card (natural) would suffice as far as the machines are concerned, but the different colors and the different printed formats are used to reduce the chance of confusing the people who may be working with the cards.

Good card design is of great importance to the successful use of punched card machines. In the first place, all of the information that will be needed (even sometime in the future) if possible should be included in the original design, for the card form is difficult to change, and it is costly and inconvenient to add information to cards that have already been punched. Secondly, poor card design may significantly increase the complexity of the processing procedures and may even cause the capabilities of the machines to be exceeded. (11: pp. 35-36)

This thesis will be based upon the equipment of one manufacturer due to obvious reasons. IBM equipment was chosen because about 90 percent of the punched card equipment in use in the United States is of this type.

The first step in the punched card process is that of recording the information in a form which can be processed--that is, punching the information into cards. Card punching is the basic method of converting source data into punched cards. The operator reads the source document and, by depressing keys, converts the information into punched holes. The machine feeds, positions, and ejects the card automatically. The operator's primary concern is to depress the proper keys in the correct sequence. (6: p.5) Another useful method for entering small quantities of information into a card is by means of "mark sensing." By using a special pencil or pen, conductive marks may be converted into punches at a speed of 100 cards per minute by the use of the mark-sensing reproducer (available only from IBM). Although many of the most prevelant errors involved in marking cards, such as failure to mark a digit or to make a readable mark, are detected by the machine, these errors cause the machine to offset the card in the stacker. The operator must then pull the card and correct the error. If this becomes frequent, the operation becomes inefficient; thus, mark sensing can be effectively used only when the persons recording the information can be motivated to take the care necessary to do it properly. Mark sensing is most efficient when the marking can be done at the point where the information originates by a person who can perform the marking as a by-product of his major work without adversely affecting his working efficiency. (11: pp. 40-41)

Card verification is quite similar to card punching except that a verifier is used rather than a key punch. Card verifying is simply a means of checking the accuracy of the original key punching. A second operator verifies the original punching by depressing the keys of a verifier while reading from the same source data. The machine compares the key depressed with the hole already punched in the card. A difference causes the machine to stop, indicating a discrepancy between the two operations. (6: p.7)

After the cards have been punched and verified, the next step in a typical punched card procedure is that of sorting the cards to arrange them in the proper sequence for further processing. Sorting is the process of grouping cards in numerical or alphabetical sequence according to any classification punched in the cards. To group cards by account, for instance, they are sorted by account number to put them in account sequence. This makes possible summarizing the cards by account. A fast automatic machine (083 sorter runs at a speed of 1000 cards per minute, 085 sorter runs at a speed of 2000 cards per minute) can be provided for arranging cards for the preparation of various reports--all originating from the same cards, but each requiring a different sequence or grouping of information. (6: p.14)

The basic steps involved in most punched card procedures include punching, verifying, sorting, and report preparation. Sometimes, however, between the punching step and that of report preparation, there may be a number of intermediate processing steps involving auxilary equipment. Some of these steps are; reproducing, interpreting, collating; matching, match-merging and calculating.

The term "reproducing" refers to the process of making a duplicate of an original deck of cards, thus preparing a single copy of each old card containing some or all of the information punched in the original card. A machine called the "reproducer" performs this operation (and several others, including mark sensing) at the speed of 100 cards per minute. The reproducer is controlled through the use of a removable panel (called a control panel) containing holes into which the ends of special wires may be inserted to provide paths for electrical impulses which travel through the machine (internally) to make the machine perform the functions desired.

So that humans do not have to read the holes, whenever it is necessary for people to read directly from cards, the "interpreter" may be used to print information that has been punched into a card on the face of that same card.

The "collator" is one of the most versatile punched card machines, performing such operations as sequence checking, selecting, matching, merging, and various combinations of these. The collator has two input feeds (primary and secondary) and four output pockets (numbered one through four). Its basic function is that of comparison, and it feeds cards and ejects them into the desired output pocket on the basis of these comparisons. The collator is frequently used to combine two files that are in the same sequence according to a specific number into a single file in that same sequence. This is called "merging." Another basic collator operation is that of "matching", in which the cards in the primary and the secondary feeds are compared and those cards that are equal are dropped side by side into pockets 2 and 3, while those secondary cards for which there is no matching primary card are placed in pocket 4, and those primary cards for which there is no matching secondary card are dropped into pocket 1. The matching and merging operations may be combined, so that the cards that match are merged together rather than being placed side by side. This operation is called "match-merging."

One of the most important steps in a punched card procedure is that of report preparation which is performed with various models of the accounting machine. This type of machine adds and subtracts, takes totals, prints, controls the spacing of the forms being printed upon, and (in conjunction with the reproducer) summary punches into new cards for balance forward purposes.

The 407 accounting machine can print a line for each card at a speed of 150 lines per minute. Through the wiring of the control panel, it is possible to eliminate part of the information on the card and to rearrange the sequence in which the information is printed across the page so that it need have no relationship to the sequence in which it appears on the card. However, the continuous forms which are fed through the machines can only space upward making it necessary that the cards be arranged in the proper sequence so that the information will print on the desired line of the form. That is to say, if card A precedes card B through the machine, then card B cannot print above card A on the form. If they both print on the same line, then all cards between the two must either not print or must also print on that line. Most models of the accounting machines include from 80 to 120 counter positions, grouped to form counters of various sizes, which may be used for adding and subtracting fields from the cards to accumulate totals. Thus, each accounting machine may be thought of as containing several adding machines, each of which may be associated with a particular field of the cards.

The punched card accounting machine can add and subtract, but it does not multiply and divide. Punched card machines that can perform all four arithmetic operations are called calculators. These machines usually read several fields from a card, perform a number of calculating steps to produce answers and punch these answers into the same card. Depending upon the model of the machine and the complexity of the problem, these machines operate at between 20 and 150 cards per minute.

Although most of these punched card calculators employ electronic circuits to perform their computations, they are not included in the category of electronic computers. The punched card calculator and the electronic computer are distinguished from one another primarily by the means through which they are controlled, and secondarily by the fact that the electronic computer frequently includes means of input and output other than the punched card. (11: pp. 49-61)

It is obvious that any single punched card machine is of little use by itself. They are designed to be used together to perform the various functions involved in data processing. The number and types of machines required in any given installation are determined by the type and volume of work to be done.

The machines presented in this chapter are considered basic machines found in almost any punched card installation. There are many more designed to perform specialized functions. Any college or university planning to investigate the mechanical methods of recordkeeping will find that there are machines available to perform any clerical function involving institutional records.

CHAPTER IV

INTRODUCTION TO ELECTRONIC COMPUTERS

Machines are devised by men for a purpose. In the case of data processing machines, the purpose can be expressed: they offer man a means to increase his productivity.

They do this in two ways. First, they enable man to increase his output per hour and the quality of his output; this is true whether it be in research, production, problem solving, or the distribution of goods and services. Second, these machines increase productivity by encouraging careful and intelligent planning.

Many changes have taken place in the last century and in many respects, they are as significant as the changeover from an agricultural to an industrial nation. Science has moved into the forefront of human activity. Research has grown to a multibillion dollar a year undertaking. New technology has provided a new impetus for corporate growth. Service industries have multiplied. Patterns of consumer spending have changed.

As these changes gained force, they manifested themselves in many ways. Informational needs greatly increased. Data assumed new importance. Clerical tasks multiplied. Paper-handling tasks appeared as if they would overwhelm all productive activities. Today, more people are engaged in the handling, processing, and distribution of goods and services than are engaged in their production. Clerical mechanization has not kept pace with fundamental changes in our economy.

Great opportunities and challenges lie ahead. An example of what can be done is the development of magnetic character sensing for the banking industry. The estimated 10 billion checks that circulate annually in the United States present a staggering task in data handling for banks. Each check drawn on a bank must be handled at least six times before it is cancelled and returned. Even when business machines were introduced to handle part of this chore, operators were needed to transfer data from the checks to a form in which the data could be used by the machines.

Magnetic character sensing, developed by computer manufacturers in cooperation with the American Bankers Association (ABA), permits data to be read directly by both man and machine. By agreement among computer manufacturers, check printers, and the ABA, banking documents such as checks, deposit slips, and debit and credit memos can be printed in magnetic ink. Printed information about the bank of origin, depositor's account number and other essential data can be read directly by the machine. Only the specific amount of each check or deposit slip need be recorded on the document in magnetic print and this need be done only once by an operator to process the document through its whole routine.

In addition to the growing need for mechanization of clerical routines and management procedures, there is the tremendously expanded need for data processing to match the new rate of technological growth and scientific research. The demands for information are enormous. More and more, data processing systems are depended on for information to run businesses, administer institutions of higher learning, direct research, and plan for the future. Regardless of the product or problem, the nature of the enterprise or institution, wherever there is need for information upon which human judgments can be based, there may also exist a need for a data processing machine. (9: pp. 6-8)

I. COMPUTER CHARACTERISTICS

Data processing equipment falls generally into one of two categories: That which is controlled by instructions wired on a control panel (discussed in chapter 3) and that which is controlled by coded instructions in storage (stored-program concept used by computers). A "stored program system" is one that stores its instructions internally. A sequence of instructions to solve a particular problem is called a program. The individual instructions are called program steps. These program steps are converted from writing to punched cards which are loaded into the computer and placed into the storage unit (memory) of the machine. When data is fed into the computer, the stored program acts on the data to produce the desired result. (13: p. xi)

The five basic aspects of data processing are: (1) Input - is any information which is entered into a machine and processed or used in processing. It can enter the machine by means of a card, magnetic tape, paper tape, etc. (2) Storage - is a device into which data can be entered. It is held in storage until it is ready for use. (3) Control - is the means by which the machine is guided or directed to perform its functions. In stored-program machines, this is done by a program. (4) Arithmetic - is the ability to perform addition, subtraction, multiplication and division. (5) Output - is information produced or turned out by the machine as a result of processing. It is recorded in punched cards, on printed reports, on paper tapes, and/or on magnetic tapes or disks. (8: p.1)

The five functions shown above represent an over-all description. The following sections will present each unit in a little more detail.

<u>INPUT</u> - An early and still very popular method of getting data into the computer is the punched card. An obvious requirement of the punched card is that someone has to punch the holes in the first place. Punched cards, which fall into the category called computer "software", are cheap, flexible, and compatible with many types of equipment. Particularly with mathematical computations and scientific research, another type of input has become popular, that of paper tape. This in effect strings many cards together and puts them on an easily handled roll. Thus a long series of data can be punched without changing cards, and is conveniently stored for repeated use.

More efficient than paper is magnetic tape, the same kind we use in our home recording instruments. Anyone familiar with a tape recorder knows how easy it is to edit or change something on a tape reel. This is a big advantage over punched cards or paper tapes which are physically altered by the data stored on them and cannot be corrected. Besides this, magnetic tape can hold many more bits of information than paper and also lends itself to very rapid movement through the reading head of the computer. For example, standard computer tape holds seven tracts, each with hundreds of bits of information per inch (10 punched cards to an inch of tape). Since there are thousands of feet on a ten-inch reel, it is theoretically possible to pack 40 million bits on this handful of tape.

Never satisfied, computer designers pondered the problem of all the lost time entailed in preparing cards or tapes for the computer. The results are interesting. Using an Optical Scanner, computers used in the post office and elsewhere can optically read addresses as well as stamps. This optical reading input is not without its problems.

Many computers require a special type face to be used, and the post office found that its stamp recognizer was mistaking Christmas seals for foreign stamps. Improved read heads now can read hand-printed material and will one day master our widely differing human hand-writing.

If a machine can read, why can't it understand verbal input as well? This idea has been tossed around for quite some time and the simplest input system of all is well on the way to success. Computers today can recognize numbers and a few words, and the Japanese have a typewriter that prints out the words spoken to it, and IBM has a machine that will answer questions on a given subject. Simply ask the computer a question and it will give you an answer. (33: pp. 53-56)

CONTROL - Before we feed the problem into the machine, or before we give it some "raw" data to process, we had better tell the computer what we want it to do. All the fantastic speed of our electrons will result in a meaningless merry-go-round, or perhaps a machine stalling short circuit unless the proper switches open and close at the right time. This is the job of the control unit of the computer, a unit that understands commands like "start," "add," "subtract," "find the square root," "file in pocket 2," "stop," and so on. More will be said about the control unit in the section on programming. (3: p.57)

ARITHMETIC - Now that our computer has the necessary ingredients of input and control, the arithmetic or logic unit can get busy. Babbage called this the "mill" and with all the whirring gears and clanking arms his engine had, the term must have been accurate. Today's computer is much quieter since in electronic switches the only moving parts are the electrons themselves. Such switches have another big advantage in that they open and close at a great rate, practically the speed of light. (3: p. 60) Up to this point we have talked of machines that could perform operations in "milliseconds" (a thousandth of a second) and "microseconds" (a millionth of a second). To appreciate such a minute interval of time, consider a space-ship of the future traveling at 100,000 miles per hour. In one millionth of a second, the space-ship would travel approximately 1 3/4 inches. (9: pp. 29-30) The fastest computers use switches that act in "nanoseconds", or billionths of a second. In one nanosecond light itself travels only a foot. (3: p.61)

MEMORY--Early machines used electromechanical relays or perhaps vacuum tubes for memory. Punched-card files store data too. To speed up the access to information, designers tried the delay-line circuit, a device that kept information circulating in a mercury. Magnetic drums and discs are also used. Magnetic tape on reels is used more than any other memory system for many practical reasons. There is one serious handicap with the tape system, however. Information on it, as on the drum, disc, and card is serial, that is, it is arranged in sequence. To reach a certain needed bit of data might require running through an entire reel of tape. Even though the tape moves at very high speed, time is lost while the computer's arithmetic unit waits. For this reason the designers of the most advanced computers have gone to "random access" instead of sequential memory. Tiny cores of ferrite material which has the desired magnetic properties are threaded on wires. These become memory elements; as many as a hundred of them in an area the size of a postage stamp. Each core is at the intersection of two wires, one horizontal and one vertical. Each core thus has a unique "address" and because of the arrangement of the core matrix, any address can be reached in about the same amount of time as any other. Thus, instead of spinning the tape several hundred feet to reach address number 6,564, the computer simply closes the circuit of vertical row 65 and horizontal row 64, and there is the desired bit of information in the form of a magnetic field in the selected core.

Right after the development of random-access core memories came that of thin metallic film devices that do the same job as the ferrite cores but take only a fraction of the space. Some of these advanced devices also lend themselves to volume production and thus pave the way for memories with more and more information storage capability. (3: pp. 62-64)

OUTPUT - Once the computer has taken the input of information, been instructed what to do, and used its arithmetic and memory, it has done the bulk of the work on the problem. But it must now reverse the procedure that took place when information flowed into it and was translated into electrical impulses and magnetic currents. It could convey the answer to another machine that spoke its language, but man would find such information unusable. So the computer has an output unit that translates back into human language. Many computers today furnish punched cards or tape as an output. Others print the answers on sheets of paper. Still others, can produce all three. One of the greatest challenges of recent years is that of producing printing devices fast enough to exploit fully the terrific speeds of electronic computing machines. Impact printers, those that actually strike keys against paper, have been improved to the point where they print more than a thousand lines of type, each with 120 characters in it, per minute. But even this is not rapid enough in some instances, and completely new kinds of printers have been developed. One is the Charactron tube, a device combining a cathode-ray tube, something like the TV picture tube, with an interposed 64-character matrix about half an inch in diameter. Electronical impulses deflect the electron beam in the tube so that is passes through the proper matrix character and forms that image on the face of the tube. This image then is printed electrostatically on the treated paper rather than with a metal type face. With no moving parts except the paper, and the electrons themselves, the Charactron printer operates close to the speed of the computer itself, and produces 100,000 words a minute. (3: pp. 65-66)

To meet the diversified requirements of the commercial, educational, military and scientific fields, two basic types of computers have been developed; analog and digital.

In the analog computer, quantities are often represented by shaft rotations or variable voltage levels. The answers to the problems solved are frequently read off on dials or cathode ray tubes. A majority of fire control systems utilize the analog computer along with a target tracking radar. As the radar tracks the target, the antenna moves in azimuth and in elevation. Since the antenna is mechanically linked to the computer, changes in the azimuth and elevation of the target will cause corresponding shaft rotations at the computer input. This data plus ranging information, give the computer the inputs with which to calculate the anticipated future position of the target. The output of the computer could be voltage levels whose amplitudes are proportional to the azimuth and elevation at which an anti-aircraft gun should be pointed at the time of firing. Unlike the digital computer, the analog computer has only one section. Of course, it must have some sort of input sensor and an output or control system. In the example just given, the sensor would be the radar antenna and the control system would be the gun control device.

Digital computers work with actual digits or numbers and the results of computations are also in digit or number form. The input unit provides the main computer with all the information it needs to solve a problem. After the problem is solved, the computer sends the solution to the output unit where it is presented in a form which is usable to people. The main computer, often called the central processor or the processing unit, is comprised of arithmetic, control, input/output, and memory sections. These sections function together to give the computer a margin of self control, the ability to perform mathematical and logical operations, a means of storing data and a way of controlling input/output equipment. (4: pp. 12-14).

II. PROGRAMMING

The digital computer, as a processor of data, has the ability to read, remember and write information; do arithmetic, and make logical decisions. The computer can also follow a series of instructions, called a "program." The computer cannot, however, prepare its own set of instructions. This job must be performed by man. The programmer must visualize the problem as a whole, then reduce it to its component parts. He must understand the computer's capabilities and limitations. Finally, he must translate the logical steps of solving the problem into computer language. (4: p. 17) The ideal programmer is a rare type with a peculiarly keen brain that sometimes takes seemingly illogical steps to be logical. Programmers are likely to be men--or women, for there is no sex barrier in this new profession. Without a program, the computer is just an expensive contraption which cannot tell one number from another. (3: p. 57)

Telling a computer to add, subtract, divide or compare is an extremely simple assignment in itself. However, when hundreds of instructions must be combined in a prescribed sequence, the task becomes highly detailed.

Programming is defined as "the science of translating a problem to terms and instructions that a computer can understand" or, more simply, it is planning the solution of a problem. Like most plans, the program must pass through several stages before it is complete. There are four phases involved in planning a program:

1. Analysis - separating the problem into component parts.

2. Application - finding how the problem can best be solved with the computer.

3. Flow Charting - using a symbolic diagram to depict how the computer will solve the component parts of a problem.

4. Coding - translatting the flow chart data into usable computer instructions.

<u>ANALYSIS</u> - In preparing a program for a computer, the programmer must ask himself "what is the problem and what results are desired"? Perhaps the results must be output in the form of 100,000

stock dividend checks. Maybe the output is to be a printed listing of all subscribers to a national magazine who live west of the Mississippi, or, the problem may be to keep an up-to-date stock inventory for a large mail order house. Once the results are known, it is necessary to decide what information is needed to obtain these results. For example, in a payroll problem, the computer works with employee names, hours worked, pay rate, tax deductions, and other pertinent data. In an inventory problem, input would probably consist of a current inventory record, a new products record, and a record of changes to be made to both. By knowing what input is required, the programmer then decides what operations must be performed on the input to yield the desired output.

APPLICATION - When a programmer completely understands the problem, he then considers it in the light of what computer equipment should be employed to solve the problem in the fastest and most efficient way. Since every problem is different, special consideration may be involved. The problem could have huge volumes of input information that must be changed before the computer can use it, or, a large amount of printed material may be required as output. (4: pp. 17-21)

FLOW CHARTING - The flow chart to some extent parallels the way our own brains solve logic problems, or at least the way they ought to solve them. For example, a computer might be instructed to select the smallest of three keys. It would compare A and B, discard the larger, and then compare the remaining key with C, finally selecting the proper one. This is of course such a ridiculously simple problem that few of us would bother to use the computer since it would take much longer to plot the flow chart than to select the key by simple visual inspection, but the principle is the same. (3: p. 58)

In order to visualize the sequence of operation, programmers find it necessary to draw a logical diagram depicting how the computer would look at a problem. The programmer must always keep in mind that the operations which the digital computer can perform may be separated into three main categories: (1) Transfer - operations which move data to or from the computer as well as within the computer. Arithmetic - operations which include addition, subtraction, multiplication, and division. Logical Decisions - operations which compare data according to relative magnitude. (4: p. 22)

CODING - After the flow chart is prepared, the programmer knows what the computer is to do; the computer does not. The next phase of the plan is to translate the flow chart symbols into instructions that are intelligible to the computer's control section. Instructions and data which are required by the computer to solve a problem are stored within the computer's main memory in specified locations called addresses. These addresses are numbered in a manner similar to that used by a hotel keeper to number the pigeon holes in which are kept room keys and guest's mail. When one hears a remark such as, "the address of the division instruction is 078", it should be understood that this means, "the division instruction is in location 078 of the computer's memory. Each address is capable of holding one computer word. There are two kinds of computer words: the data word and the instruction word. A data word, as the name implies, contains information needed to solve a problem. Quantities to be added, subtracted, divided, multiplied, shifted or the results of these operations would all be classified as data words. An instruction word, on the other hand, is a computer word which tells the computer what to do. Each instruction usually specifies three things: (1) the operation to be performed. (2) the address of the data to be operated upon. (3) the address of the next instruction. To put it more simply, the three steps above answer the questions, "what am I to do, where do I obtain the necessary information and where do I find the next instruction?" (4: pp. 25-27)

When the coding is complete, the programmer's only worry is that an error might exist in the program. He must assemble his program and then test it on actual data. If errors are present in either the assembly or the testing routines, the program must be "debugged" and tested again. This procedure must be followed until the program is free of errors. Then and only then is the programmer's work complete.

III. GROWTH OF COMPUTERS

The early 1950's saw the introduction of medium and large scale data processing systems, specifically designed to take over the mounting clerical chores of a growing nation.

Though essentially similar to previous computers in the way they processed data, these new systems differed substantially in various parts of their make-up. In scientific research, most problems call for relatively small numbers of items to be subjected to intensive machine processing. In business operations, the reverse is more often true. Here the need is for machines that accommodate vast numbers of items while the processing, by comparison, is ordinarily quite simple.

Early computers had used punched cards and paper tapes for the input of information. Now a method was perfected for storing information as magnetized spots on magnetic tape. This new technique provided input speed 50 to 75 times that of cards. It brought improvement in input, output, and storage.

After the Korean War, man's need always seemed to be one jump ahead of the computer's ability to handle the logical and arithmetic labors of his reasoning. The demand quickened especially in such fields as nuclear physics and space technology where work on the H-bomb and ballistic missiles presented problems that put a severe strain on the capacities of existing machines. Still more speed was needed. About this time a substitute for earlier devices appeared and was called magnetic core storage. Almost at the same time, other engineers perfected magnetic drum storage. Access time on the drum was substantially slower than that on the core system, but storage capacity was increased. While access time on the drum was slower than that of the core, it was faster than that of magnetic tape.

Other conditions peculiar to business led to still more developments. A major one is a system that overcomes a problem--batching. For example, when magnetic tapes are used to store information in a computer, the user must accumulate information in batches before putting it on tape. Otherwise, the computer would be costly and time consuming. When this limitation is applied to business practice, it means that each item of information can be only as current as the batch in which it is bundled for delivery to the computer. In ordinary operations, hours and sometimes days may elapse between batches. The limitation is compounded when the user calls for the retrieval of a piece of information. The computer is forced to search through a long reel of information for the piece. Access is slow; time is lost. Batching and searching requirements frequently present serious drawbacks, even in scientific work. In business, the difficulty becomes much more acute, especially in accounting procedures. Here is a requirement that can only be met by in-line data processing.

In-line data processing came with the development in the middle 1950's of random access systems, such as the IBM 305 RAMAC. A stack of magnetic disks in the RAMAC stores up to 10 million digits of information. The disks rotate at 1,200 rpm past access arms that move quickly to any point of any disk to deposit or retrieve data.

Continuing developments in pulse electronics and solid state physics led to still newer and better components. There are practical limits to the size and capacity of a machine operated on vacuum tubes. Tubes are bulky; they demand considerable power; they produce heat and create air conditioning problems.

In the newer computers, the vacuum tube was replaced by a smaller semi-conductor diode that has the advantage of demanding less power. A further advance came when tiny transistors were introduced. Not only can these transistors be packed into smaller units, but they have greater reliability. The change-over to transistors is now accomplished in the latest computers to come on the market.

Research scientists have already advanced to still further stages in design. Some are studying the use of microwave elements as a medium for performing computer logic. Others are studying the behavior of materials and electrons at extremely low temperatures.

As always, the objective is to develop a better, more versatile, more useful computer--one that will work faster, store more information, demand fewer instructions, require less power, and occupy less space. (9: pp. 9-10)

CHAPTER V

CONSIDERATIONS FOR DEVELOPMENT OF THE COMPUTER CENTER

Computers have enabled states and their higher institutions to solve or to make manageable complex problems associated with the planning, development and conduct of higher education.

The computing center of any major college or university can serve not only the academic departments but also provide the staff and laboratory facilitities for instruction in data processing and computer programming. It is possible for projects to be distributed over the fields of agriculture, business, economics, engineering, education, physical education, english, government, home economics, mathematics, music science, sociology and industrial education to name a few.

In many schools, major portions of the accounting and payroll activities of the business office and the registration procedures and student record keeping of the registrar are being carried out with the aid of computers.

A new subject matter field, usually called "computer science", which the existence of a center with adequate staff enables the school to offer has not been precisely defined. It is, however, interdisciplinary in nature and involves such topics as the theory and application of computer programming, problem-solving techniques, methods of applying computers to various fields, information storage and retrieval, design of computers, and information theory. Several institutions already have computer science departments or other departments which embrace part of this material. Any school should include in its long-term planning the possibility of offering computer science whether it does so in a separate computer science department or through other departments of the institution.

The selection of equipment for the computer center depends on several factors, such as the needs of the school, the type and extent of use that is anticipated for the computer, and the financial resources and personnel that are available. These factors vary greatly from institution to institution. No set pattern will work for all colleges and universities. The equipment should be chosen only after consultation with computer experts and not solely on the basis of recommendations by the sales representatives of computer manufacturers.

There are two words which are used in computer terminology that must be covered in any discussion on equipment. The term "hardware" refers to the electrical and mechanical devices used in the machine processing of information and was covered in Chapter IV. "Software" is taken to mean a computer program library or programming support. The computer hardware can be used only by persons well acquainted with programming without an adequate program library. A good program library contains not only a well assorted set of special-purpose programs (such as those for performing the standard statistical computations) and a well written set of mathematical subroutines (such as those for computing the elementary functions, multiply, divide, and square root) but also even more important programs for simplifying the programming process itself and for monitoring the execution of the program on the computer. Because of the fact that machine language of computers is extremely difficult and tedious to use, special programs have been written for every modern computer which simplify this programming task in a variety of ways and which make the programming language easier to understand, to learn, and to use. The computer is then used to translate these languages into its own machine language. Some translation programs such as those for the widely used languages (COBOL, FORTRAN, SPS, AUTOCODER) are usually furnished by the computer manufacturer. Other translation programs for less general languages to be used with the specific computer should also be part of the manufacturer's software package together with the standard subroutines for mathematical functions.

Space requirements will vary according to the institution and are determined by a number of factors. The most obvious of these are the size of the contemplated computer and the availability of space and funds. Experience has shown that computing centers tend to expand much more rapidly than most other departments. Therefore, over-all planning for the future is particularly important; for the expansion of computer facilities tends to impose special problems, such as the expansion of air conditioning, electrical power supplies, and space, both for the computer and supplies. If instruction is anticipated, adequate classroom space must be made available.

No university should plan a computing center without making adequate provisions for a competent director and a suitable staff. It is essential that the director appreciate the full scope of the service to instructional, research, and administrative functions of the university which the center can render. He should be fully aware of the possibilities of computing and data processing for the university as a whole including departments which have not begun to exploit the computer in their research and teaching. He should be willing to cultivate interest in computing in areas which should be making use of the computing center but might not do so unless encouraged and trained.

Once a suitable director is chosen, it is essential that he be provided with adequate clerical and technical staff. The size of staff will depend upon the scope of the activities which the center is expected to perform. The types of personnel required may include programmers; systems analysts; machine room supervisors; operators for the computers and for the peripherial equipment such as keypunch, sorting, or collating machines; consultants to work with users having research or instructional programs of their own for use in classes or personal research projects; instructors in programming; and student assistants for grading papers connected with programming and for helping student programmers. In smaller centers, all these functions may be required; but it is frequently possible for a single individual to serve in many of the capacities. After a permanent staff is made available and trained, additional part-time help can frequently be obtained from student assistants who become familiar with programming and with operating the computer.

Whenever recommendations concerning the administrative position of the center are within the academic framework of the institution, it is apparent that the financial support of the center should be the responsibility of the central administration of the institution. The computing center should be a separately budgeted entity. The budget allocation should be sufficient to support the basic operating costs and to enable the center to carry on its educational and research activities without relying on income from outside sources.

Many schools also provide partial support for the computing center by making charges for services both to users from outside the institution and to departments or research projects within the institution. In the case of externally supported research, this is a necessary device for obtaining funds actually intended for computing services rendered to projects supported by local budgets, however, the increased bookkeeping costs for internal transfer of funds are so high and the amounts involved so difficult to estimate adequately for budget-building purposes that a more satisfactory arrangement is to support all services provided for departmental projects by direct allocation of university funds to the center. One may draw the analogy between the services provided by the computing center and those provided by the library. Certainly, few libraries could operate successfully if their budgets had to come in fragmentary fashion from the budget of individual departments and users.

Two important points should be emphasized: (1) regardless to the source of funds for the operation of the computing center, the financial arrangement should not interfere with the use of the center. (2) any planning for the future must always take into consideration the possibility of rapid expansion. (2: pp. 1-24)

CHAPTER VI

SUMMARY AND CONCLUSIONS

Future computers will inevitably introduce changes in the way we work and in the way we learn. For the present though, computer users are handicapped in communicating with these machines. Instructions must be coded laboriously into machine language. Instructions conveyed in a few spoken words to a human being may require hundreds of logical movements in a computer--and this is a problem because the computer must be instructed in each movement.

The new science of automatic programming seeks to make programming easier and more manageable. The goal is to build and program computers so that they accept instructions in everyday English. Ultimately, computer scientists hope to develop machines that read ordinary printed matter and respond to spoken words. Already there is one significant step forward in the case of machines that read. Magnetic character sensing, as previously indicated in Chapter IV, utilizes numbers and letters printed in a way that can be read by machines as well as man. The growth and development of data processing and computer technology indicate strong implications toward future success in the transition from manual to mechanical records in colleges and universities.

Computers, by 1980, will probably be quite different from today's. Storage and processing units as powerful as today's largest may be the size of a television set. Already there are systems where a single computer serves a number of inquiry stations. Such systems can be expanded to produce larger net-works and integrate widely scattered business operations. Instead of handing an employee his paycheck, a paymaster may simply instruct a computer housed in a bank, to credit the employee's earnings to his bank account. At this point, a chain reaction begins. The company's account is debited by the amount of the paycheck. This information goes to the company's accounting machines for processing and storage. Now, assume that the employee wants to buy something that cost more than he wishes to pay for in cash. The salesclerk asks for identification, a card that identifies the customer to the salesclerk and to the computer (most likely his social security card). The clerk instructs the bank computer to debit the customer's account by the amount of his purchases. The same amount is credited automatically to the store's account. Information on the sale goes to the store's computer for processing with sales, financial, and inventory data. Periodically, the customer gets a statement on his deposits, withdrawals, and computer transactions.

Other scientists have turned their talents to developing what they call information centers. The science of information retrieval by machine is under rigorous study. As our society grows, the information it generates will increase; the task of finding what one is looking for will become increasingly difficult and time consuming. Information centers of the future would collect, catalog, and retrieve information electronically by machine. Queried about a subject, a center could provide specific source references, cross-references, and subdivisions of subject matter. Or, asked a question, it could give a direct answer. Such a development would mean immediate access to more information than was ever before instantly available. A man might never have the ability to know all that he might want to know, but he would have the means of finding it as he had need.

In a future society, man will have greater and more pressing need for business machines than ever before. These needs, in turn, will dictate machine advances. What will these advances mean? They signify continuing and hopeful advance in human progress. And because these machines have so many applications, because they can be used in so many ways, they hold out the promise of progress in the use we make of our time, progress in the way we employ our talents, progress in the search we make for learning and knowledge.

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